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EXPERIMENTAL STUDY OF EFFECTS OF ELECTRON IRRADIATION FROM 20 keV TO 1 MeV ON A POLYETHYLENE TEREPHTHALATE CAPACITOR-TYPE METEOROID DETECTOR

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Langley Research Center
Langley Station, Hampton, Va.

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EXPERIMENTAL STUDY OF EFFECTS OF ELECTRON IRRADIATION FROM 20 keV TO 1 MeV ON A POLYETHYLENE TEREPHTHALATE CAPACITOR-TYPE METEOROID DETECTOR

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SUMMARY

A capacitor-type meteoroid detector was irradiated with low-energy electrons. Under irradiation, this detector produced pulses which were counted in a satellite-type detection circuit. At liquid-nitrogen temperature, the number of pulses for a given dose was found to be essentially independent of both the battery voltage (over a range from 0 to 135 V) and the electron dose rate (over a range from 3.1×10^{7} e/cm^{2}-sec to 3.1×10^{10} e/cm^{2}-sec). The greatest number of pulses was observed at liquid-nitrogen temperature (77° K). The number of pulses decreased with increasing temperature; however, radiation-induced pulses still occurred at temperatures on the order of 363° K. It is believed that the pulses were caused by electron charge storage and subsequent discharge within the polyethylene terephthalate dielectric of the detector. The results of a few preliminary tests of a coincidence-type detector, designed to discriminate against radiation pulses, are also presented.

INTRODUCTION

The presence of meteoroids in space (refs. 1 and 2) constitutes a hazard to spacecraft. The potential hazard is so great that a large program utilizing research satellites specifically designed to study the penetrating ability of meteoroids has been initiated. One such satellite was Explorer XVI (refs. 3 to 6) which utilized several different types of meteoroid detectors.

The importance of gaining new information on the penetration capabilities of meteoroids has made it necessary to develop new and improved penetration detection systems. The capacitor-type meteoroid detector is one of the new systems. The meteoroid detectors based on this principle have been used on Explorer XXIII and Pegasus spacecraft I, II, and III (refs. 7 and 8). The detector sizes and materials however, were different from those used in this experiment. The detector for this system is a flat capacitor composed of alternating layers of metal and dielectric. The detector is charged to a given constant voltage by a battery. A meteoroid penetrating the detector temporarily creates a conducting plasma at the point of penetration. Conduction through the plasma at least partially discharges the capacitor for a brief interval. The plasma dissipates almost immediately and the capictor recharges to the initial voltage level at a rate governed by the time constant of the circuit. The discharge-and-charge cycle is counted as one penetration.

The present investigation is concerned with the effect of the electron environment in space (refs. 9 to 12) on the performance of capacitor-type meteoroid detectors. Sample detectors were irradiated with 20 000-eV (20 keV) to 1 000 000-eV (1 MeV) electrons while at temperatures between 77° K and 363° K and vacuums between 2×10^{-8} torr and 10^{-5} torr $\left(1 \text{ torr} = 1.33322 \times 10^{2} \text{ N/m}^{2}\right)$. The electron dose rate was varied over several orders of magnitude during the course of this investigation. Circuits similar to possible satellite pulse-detection systems were used to monitor the output of the sensors while under irradiation.

The detectors tested herein are not identical in configuration to those intended for any specific payload. Furthermore, the actual electron exposure in space can vary over many orders of magnitude depending upon the payload mission. The present results are intended only to indicate the general nature of the effects which might be encountered. The actual assessment of the problem for a given payload requires a combination of radiation tests on the actual flight hardware and a knowledge of the electron exposure and temperatures anticipated in the desired orbit.

APPARATUS AND TESTS

Accelerator and Beam-Handling Equipment

A 1-MeV constant-potential cascaded-rectifier electron accelerator of the type described in reference 13 was used for these tests. This accelerator provided electrons with kinetic energies from 20 keV to 1.0 MeV.

The accelerator energy was calibrated with a surface-barrier solid-state radiation detector which, in turn, was calibrated against suitable electron-emitting radioactive isotopes $\left(Ba^{133} \text{ and } Bi^{207}\right)$. The overall accuracy of this calibration is within 2 percent. Voltage fluctuations in the electron beam were sufficiently below the 18 keV resolution (full width at half height) of the detector that the magnitude of such fluctuations could not be determined.

The beam-handling and sample-mounting systems are shown in figure 1. The electron beam entered from the accelerator, was widened by a single-quadrupole magnetic lens, and then was swept vertically in a scan horn at a frequency of approximately 10 cps. The beam then entered a target chamber attached to the end of the scan horn.

Target Chambers

Two different target chambers were used for these tests in order to obtain the desired test temperatures. Both chambers had an opening 3 inches (7.6 cm) wide and 30 inches (76.2 cm) high facing into the scan horn. Each chamber was mounted on the scan horn (fig. 1) and had an independent vacuum-pumping system. In addition, both chambers were fitted with a rectangular tube, or finger, on which the samples were mounted (fig. 2). These fingers were filled with heated water or liquid nitrogen in order to maintain the test temperatures of 363° K and 77° K, respectively. Tests at ambient temperature were conducted with the finger empty. Target chamber vacuum during irradiation varied from 2×10^{-8} to 10^{-5} torr, depending primarily upon the temperature of the finger.

Beam-Current Uniformity

The uniformity of the spread beam was studied at the sample location by cobalt-glass dosimetry. The vertical uniformity of the beam pattern was found to be within ±5 percent. Laterally, the beam-current density was greatest at the center of the sample location and decreased by approximately 20 percent at the lateral edges of the sample.

Current-Density Measurements

Current density was monitored by an aluminum pickup plate of known area. This plate was insulated from the target chamber by a small glass plate which was bonded to the center of the temperature control finger approximately 1 in. above the sample (fig. 2). In order to measure the total dose and dose rate, the electrons captured by the pickup were conducted to ground through an integrating electrometer (1 percent accuracy). Overall accuracy of the current measuring system (primarily limited by backscatter from the plate) was approximately 15 percent.

At the lowest dose rates used herein, the integrating electrometer did not have sufficient sensitivity for accurate measurement. For these cases only, the dose rate was determined by using a more sensitive nonintegrating electrometer, and the total dose was determined from the product of the average dose rate and time.

Capacitor-Type Detector Samples

Two different configurations of capacitor-type meteoroid detectors were studied in these tests. Each of these types of detectors is discussed separately in the following paragraphs.

Single-layer detector.- The first, or single-layer, detector (fig. 3(a)) was composed of a 0.001-in-thick (0.025 mm) aluminum plate bonded to a 0.00025-in-thick (0.0063 mm) film of polyethylene terephthalate. Approximately 25 μin. (0.00063 mm) of aluminum was vapor deposited on the rear surface of the dielectric to form the second plate of the capacitor. The overall sample size was 2 by 3 in. (5.1 by 7.6 cm). Bare-wire leads were attached to both the aluminum front plate and the vapor deposit by means of a conductive silver-loaded epoxy cement. The bonding agents used throughout are identical to those of reference 14, where the tests indicated that these agents played little or no part in the observed results.

Coincidence-type detector.- The second type of detector was designed to be used in a coincidence circuit. It was constructed by bonding two of the single detector samples together, vapor deposit to vapor deposit (fig. 3(b)), with a silicone adhesive. The adhesive layer was comparatively thick and not uniform in thickness. Resistance measurements showed that the two vapor deposits were in electrical contact with each other; even so, the bare-wire leads to each vapor deposit were physically connected together in order to further insure electrical contact throughout the tests.

Sample Mounting

The single-layer detector was bonded directly to the mounting finger (fig. 2) with the 1-mil (0.025 mm) aluminum plate facing the electron beam. In this instance, the rear layer of the detector was operated as the grounded side of the test circuit.

The coincidence detector was mounted by bonding it to a 1/2-mil-thick (0.013 mm) sheet of polyethylene terephthalate which, in turn, was bonded to the temperature control finger in the vacuum target chamber. Since both the front and the rear plates of the detector were charged, the polyethylene terephthalate sheet was necessary in order to insulate the rear layer of the sensor from the grounded chamber. In order to provide the maximum possible isolation between the two halves of the detector, each bare-wire lead was brought out of the target chamber on its own individual vacuum feed-through plate.

All electrical leads within the vacuum chamber were bare wire. Bare wire was used since the data of reference 14 indicated that the irradiation of insulated wire might produce radiation-induced transient signals in the output leads from the detector.

Test Circuits

Single-layer-detector circuits.- The primary instrumentation used for pulse detection with the single-layer detector is shown schematically in figure 4(a). This circuit was a "breadboarded" version of a possible satellite electronics system for a single-layer meteoroid detector. With this circuit the front plate of the detector was charged to a negative 13 V. In essence, the circuit of figure 4(a) acted as a single-shot multivibrator which triggered only on positive pulses with amplitudes greater than 1 V. (Positive pulses are defined herein as being those in the same direction as a pulse caused by a direct short across the detector.) When triggered, the circuit produced a pulse approximately 4 msec long with an amplitude of 4 V. The output pulses from the test circuit were recorded by one channel of a direct-writing oscillograph.

In order to obtain photographs of the wave shape of signals arising in the detector sample, a camera-equipped oscilloscope was placed in parallel with the pulse detection circuit. However, for tests in which only the signal wave shape was of interest, the circuit of figure 4(b) was used.

Coincidence-detector circuits.- The circuit shown in figure 5(a) was used with the coincidence-type detector. It too was a "breadboarded" version of a possible satellite instrument package. This circuit was essentially two of the single-layer circuits with a coincidence-gated output. Positive pulses greater than 2 V occurring in the front layer alone, in the rear layer alone, and in both layers simultaneously (within 1 msec) were recorded on three separate channels of the oscillograph. Figure 5(b) shows the circuit used in order to obtain photographs of the wave shape of signals arising within the coincidence-type detector.

RESULTS AND DISCUSSION

Single-Layer Capacitor Detector

General results presented herein for the single-layer detector were obtained with only one sample. One detector was used because a large variability between polyethylene terephthalate samples was indicated from prior unpublished tests of many similar samples; however, the results presented herein are indicative of the general trends which may be expected from different samples. Although physical explanations for some of the observed phenomena are offered herein, the intent of the present paper is primarily to present the observed data. This paper contains no attempt to develop a full theory to account for the fundamental processes occurring in the samples.

Radiation-induced pulses.- Pulses consisting of a rapid discharge followed by a slower recharge following the circuit time constant were observed while the detectors were exposed to electron radiation. The radiation-induced pulses were counted as penetrations by the simulated satellite detection circuit which, as previously noted, had a sensitivity of 1 V. A complete tabulation of the data for the single-layer detector is presented in table I.

Effect of kinetic energy.- The effect of electron kinetic energy on the number of radiation-induced pulses for a given total dose $\left(3.75 \times 10^{13}\ e/cm^2\right)$ is shown in figure 6. These data were obtained at liquid-nitrogen temperature and at dose rates of 3.1×10^{9} and $3.1 \times 10^{10}\ e/cm^2$-sec. Figure 6 shows that, as the kinetic energy was increased initially, the number of pulses increased. This initial increase corresponds to an increase in the number of electrons penetrating through the aluminum front plate and into the dielectric. Pulses were obtained at energies as low as 20 keV with the greatest number of pulses occurring around 40 keV. For 0.001-in. (0.025 mm) aluminum, which has a calculated mass per unit area of 7 mg/cm^2, about 55 keV to 60 keV is required for electron penetration. The mass of the 0.001-in. (0.025 mm) aluminum front cover of the sample tested herein could not be measured because the sample was damaged on removal from the cold finger. However, the mass per unit area of the front plate of several other samples, which were made at the same time and in the same way as the test sample, were measured. It was found that the aluminum front plate measured 0.001 in. (0.025 mm) in thickness but when weighted was found to be 5 mg/cm^2 for an average calculated thickness of 0.0007 in. (0.018 mm). This lesser mass per unit area corresponds to the range of 45 keV electrons in aluminum. It could be that the porosity of the aluminum was great enough to permit electrons to penetrate to the dielectric with the accompanying secondary electrons. This would produce pulsing at energies lower than transmission calculation would predict for the 0.001-in. (0.025 mm) aluminum plate. When the energy was increased still further, the number of pulses for the same total dose was reduced. This reduction corresponds to an increase in the transmission of electrons completely through the dielectric. At electron energies above 200 keV, the same total dose produced no pulses. (Tests at 0.4, 0.6, 0.8, and 1 MeV, not shown in fig. 6, also produced no pulses.) Thus, the number of pulses obtained appears to be a function of the number of electrons stopped within the dielectric layer of the detector.

Pulse signature.- Photographs of sample pulses are shown in figure 7. These pulse signatures were obtained with the circuit shown in figure 4(b). The pulses typically started with a rapid discharge to a random voltage level. The discharge time was beyond the response of the oscilloscope and is presumably on the order of a few nanoseconds in length. The discharge was followed by a recharge at the rate of the time constant of the circuit to the initial voltage level. A noticeable ringing occurred during the first few microseconds after discharge. This ringing is typical of the radiation-induced pulses discussed in this paper. Possibly the ringing may be caused by a small amount of inductance in the pulse detection network or in the test sample itself.

In figure 7(a) the pulse height is substantially in excess of the 15 V to which the capacitor was charged. Figure 7(b) shows a pulse greater than 80 V which was obtained under the same conditions. Not all of the radiation-induced pulse heights were this great. Pulses were observed with amplitudes ranging from less than 1 volt to as much as several hundred volts.

Since voltage pulses greater in amplitude than the plate voltage were recorded, simple conduction effects are not adequate to explain the observed signals. Instead, it is postulated that the radiation-induced pulses are caused by electron charge storage within and subsequent release from the dielectric layer of the samples. A more complete discussion of the proposed mechanism is presented in reference 14, which is closely related to the present work, as well as reference 15, which is fundamentally related to the present problem.

Effect of battery voltage.- A limited number of tests were conducted in order to determine the effect of battery voltage on the number of pulses. Different battery supplies were substituted for the normal battery supply of the simulated satellite circuit for these tests. In addition, a voltage-divider network was placed across the input of the detection circuit in order to maintain a constant ratio of triggering voltage to battery voltage. For battery voltages of 0, 13.5, 45, and 135 V the triggering levels were 1.0, 1.0, 3.5, and 9.6 V, respectively.

Figure 8 shows that battery voltage had little significant effect on the number of pulses counted under these conditions. The pulse heights observed in these tests, as in all other tests, varied from less than 1 volt to several hundred volts.

Effect of dose rate.- Most tests were performed at relatively high dose rates $\left(3.1 \times 10^9 \text{ to } 3.1 \times 10^{10} \text{ e/cm}^2\text{-sec}\right)$ compared to the dose rates in space which are more typically on the order of 10^5 to 10^7 e/cm^2-sec. Consequently, a number of tests were conducted at reduced dose rates. Figure 9 (reproduced from ref. 14) shows the effect of dose rate on the number of pulses. At liquid-nitrogen temperature, only a small effect of dose rate, if any, was observed. Indeed, the possible effect of dose rate shown in figure 9 is of the same order of magnitude as the statistical difference between repeated tests. It appears that for polyethylene terephthalate at 77° K, dose-rate effects are of secondary importance; that is, the number of pulses obtained depends primarily upon the total dose received by the sample. Only two dose rates were used at room temperature (297° K) and at elevated temperature (363° K). From these tests, it appears that there is a reduction in the number of pulses for a given total dose at these temperatures as the dose rate is reduced. Additional information on dose-rate effects at warm temperatures is presented in reference 14.

Effect of temperature.- From figure 9, the largest number of pulses occurred at liquid-nitrogen temperature (77° K). Tests at successively increasing temperatures showed a decreasing number of pulses for the same total dose. If electron trapping is assumed to occur within the dielectric, then the temperature effect shown in figure 9 would be expected. The removal of electrons from traps within the dielectric by thermal agitation would be a function of temperature. Since at lower temperatures less thermal agitation is available to remove electrons from traps, a more rapid buildup of charge to the point of discharge would be expected.

Coincidence-Type Capacitor Detector

An attempt was made to produce a successful capacitor-type meteoroid detector by using a two-layer capacitor in a coincidence circuit. On the premise that radiation-induced pulses would occur randomly in either of the two layers but that penetration pulses would occur simultaneously, a coincidence detector should reject radiation pulses but still count true penetrations. As a check on this possibility, a coincidence-type detector was improvised by gluing together two single-layer detectors (fig. 3(b)). With this arrangement, the circuit of figure 5(a) was used. This circuit counted pulses occurring within 1 msec in both layers as well as those occurring independently in either layer.

All tests of the coincidence detector were conducted at liquid-nitrogen temperature (77° K) and at a dose rate of 3.1×10^{10} e/cm^2-sec. A complete tabulation of the data is presented in table II.

Figure 10 shows the effect of kinetic energy on the number of pulses for a given electron dose $\left(3.75 \times 10^{13}\ e/cm^2\right)$. Some pulses in the front layer occurred independently of the rear layer; however, pulses from the rear layer, for the most part, occurred in coincidence with pulses from the front layer. A 50-percent reduction in the number of pulses counted as penetrations was observed.

Figure 11(a) shows the signature of the pulses that occurred in each of the two layers. Ringing was previously noted for the single-layer detector discussed earlier in this paper. For the coincidence-type detector, the ringing was substantially greater and the ringing from a pulse that occurred in one layer of the detector tended to be picked up by the second layer. This cross talk was apparently the cause of the coincidence pulses.

The ringing was reduced by the insertion of a 221-Ω damping resistor in each signal lead. (See fig. 5(a).) The tests were then repeated with the damping resistors in place. The reduction of ringing is evident in figure 11(b). Figure 12 shows the results of the tests with these damping resistors in place. The general behavior of the front layer was similar to that of the single detector shown previously in figure 6. For reasons not yet clearly understood, the rear layer did not pulse as much as had been expected; however, the number of coincidence pulses was extremely small. A comparison of the total number of pulses in the front and rear layers with the total number of coincidence pulses throughout the entire energy range might indicate a reduction of approximately two orders of magnitude in the number of false penetration signals.

Although the rejection rate for pulses occurring in the front layer is quite high, almost all pulses which occurred in the rear layer involved a coincidence pulse. This result may be caused only by the particular test arrangement; on the other hand, it could also indicate a basic defect in the coincidence technique. However, a possibility may exist that radiation-induced pulses may be discriminated against in a coincidence detector. A substantial amount of development work would be required before final proof could be obtained.

SUMMARY OF RESULTS

This study of the effect of 20 keV to 1 MeV electron irradiation on a capacitor-type meteoroid detector indicates the following results under the conditions tested herein:

1. Electron irradiation produced pulses in capacitor detectors. The pulses consisted of a very short discharge followed by a slower recovery controlled by the time constant of the overall circuitry.

2. The radiation-induced pulses were counted as penetrations by the simulated satellite circuit used in these tests.

3. The number of pulses observed for a given total dose was a function of the incident electron kinetic energy. As the kinetic energy is increased, the number of pulses increased and subsequently decreased, apparently due to greater transmission through and less deposition of electrons in the dielectric material.

4. The number of pulses counted for a given total dose increases as the sample temperature decreases.

5. The number of pulses counted is essentially independent of the battery voltage.

6. There is only a negligible dose-rate effect at liquid-nitrogen temperature (77° K); that is, the number of pulses produced by a given total dose is essentially independent of the dose rate at which the dose is delivered (for dose rates from 3.1×10^7 to 3.1×10^{10} e/cm^2-sec).

7. Brief tests of a coincidence version of the detector indicate a possibility of discriminating against radiation-induced pulses by coincidence techniques.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Station, Hampton, Va., November 18, 1965.

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TABLE I.- DATA FROM TESTS OF A SINGLE-LAYER DETECTOR

Electron kinetic energy, keV	Electron dose rate, e/cm^2-sec	Detector potential, V	Detector temperature, ^{o}K	Number of pulses for 3.75×10^{13} e/cm^2
20	3.1×10^9	13.5	77	44
30	3.1×10^9	13.5	77	67
41	3.1×10^9	13.5	77	68
52	3.1×10^9	13.5	77	44
52	3.1×10^9	13.5	77	43
52	3.1×10^9	13.5	77	41
52	3.1×10^9	13.5	77	41
52	3.1×10^{10}	13.5	77	41
52	3.1×10^8	13.5	77	39
52	3.1×10^8	13.5	77	41
52	3.1×10^7	13.5	77	36
52	3.1×10^{10}	13.5	297	40
52	3.1×10^9	13.5	297	29
52	3.1×10^{10}	13.5	363	22
52	3.1×10^{10}	13.5	363	30
52	3.1×10^9	13.5	363	8
52	3.1×10^9	0	77	48
52	3.1×10^9	45	77	51
52	3.1×10^9	135	77	37
75	3.1×10^{10}	13.5	77	45
75	3.1×10^9	13.5	77	38
97	3.1×10^{10}	13.5	77	15
97	3.1×10^9	13.5	77	27
120	3.1×10^{10}	13.5	77	5
120	3.1×10^9	13.5	77	12
143	3.1×10^{10}	13.5	77	8
143	3.1×10^9	13.5	77	11
166	3.1×10^{10}	13.5	77	13
166	3.1×10^9	13.5	77	10
211	3.1×10^9	13.5	77	0
268	3.1×10^9	13.5	77	0
400	3.1×10^9	13.5	77	0
600	3.1×10^9	13.5	77	0
800	3.1×10^9	13.5	77	0
1000	3.1×10^9	13.5	77	0

TABLE II.- RESULTS FROM TESTS OF A COINCIDENCE-TYPE DETECTOR

[Electron dose rate, 3.1×10^{10} e/cm^2-sec; potential, 13.5 V; temperature, 77° K]

Electron kinetic energy, keV	Total counts in -		
	Front sensor	Rear sensor	Coincidence
No damping resistors			
41	75	37	36
52	53	24	24
64	41	25	24
75	30	19	19
86	22	14	14
97	22	8	8
109	5	5	5
120	6	1	1
132	13	3	0
143	12	0	0
154	10	1	0
166	6	1	0
221-Ω damping resistor in each signal lead			
41	14	0	0
52	20	1	1
	16	1	1
	14	1	1
64	15	2	2
75	15	1	1
86	10	0	0
97	7	0	0
109	1	0	0
120	1	0	0
	1	0	0
132	1	0	0
143	0	0	0
154	0	0	0
166	0	0	0

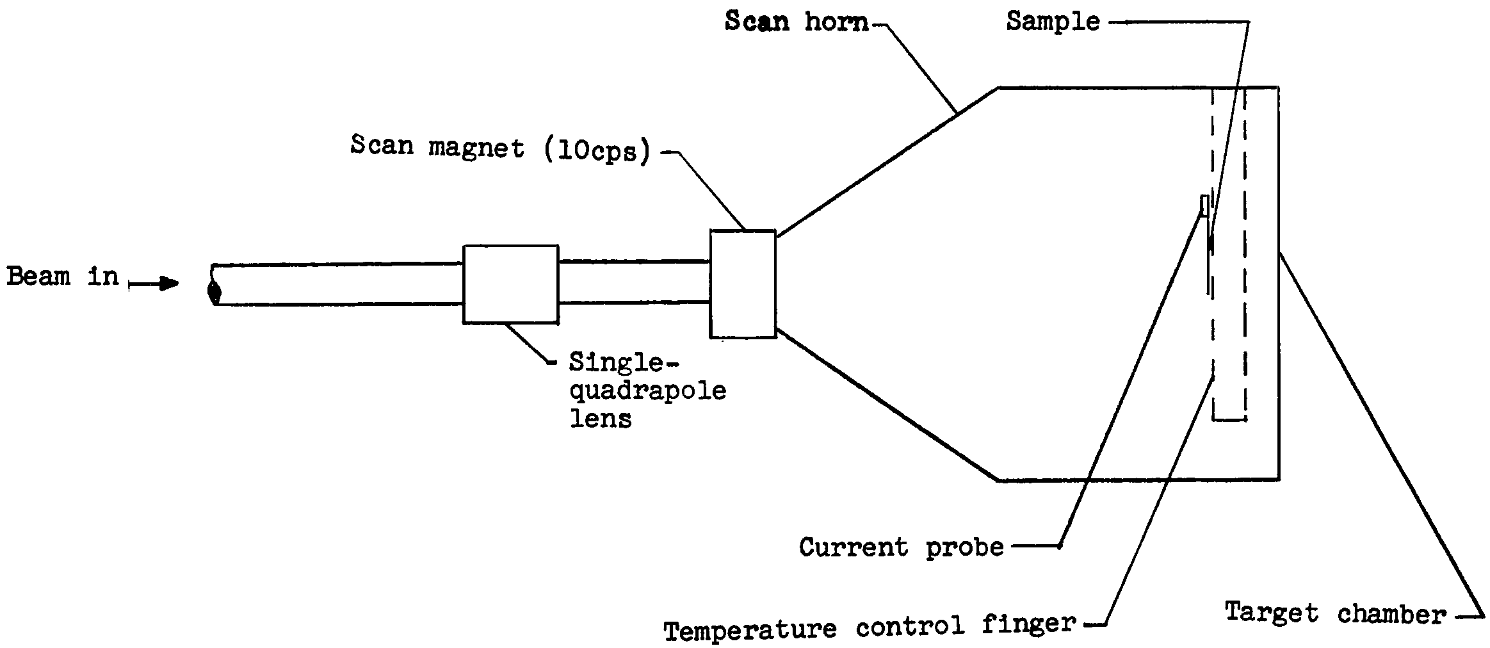
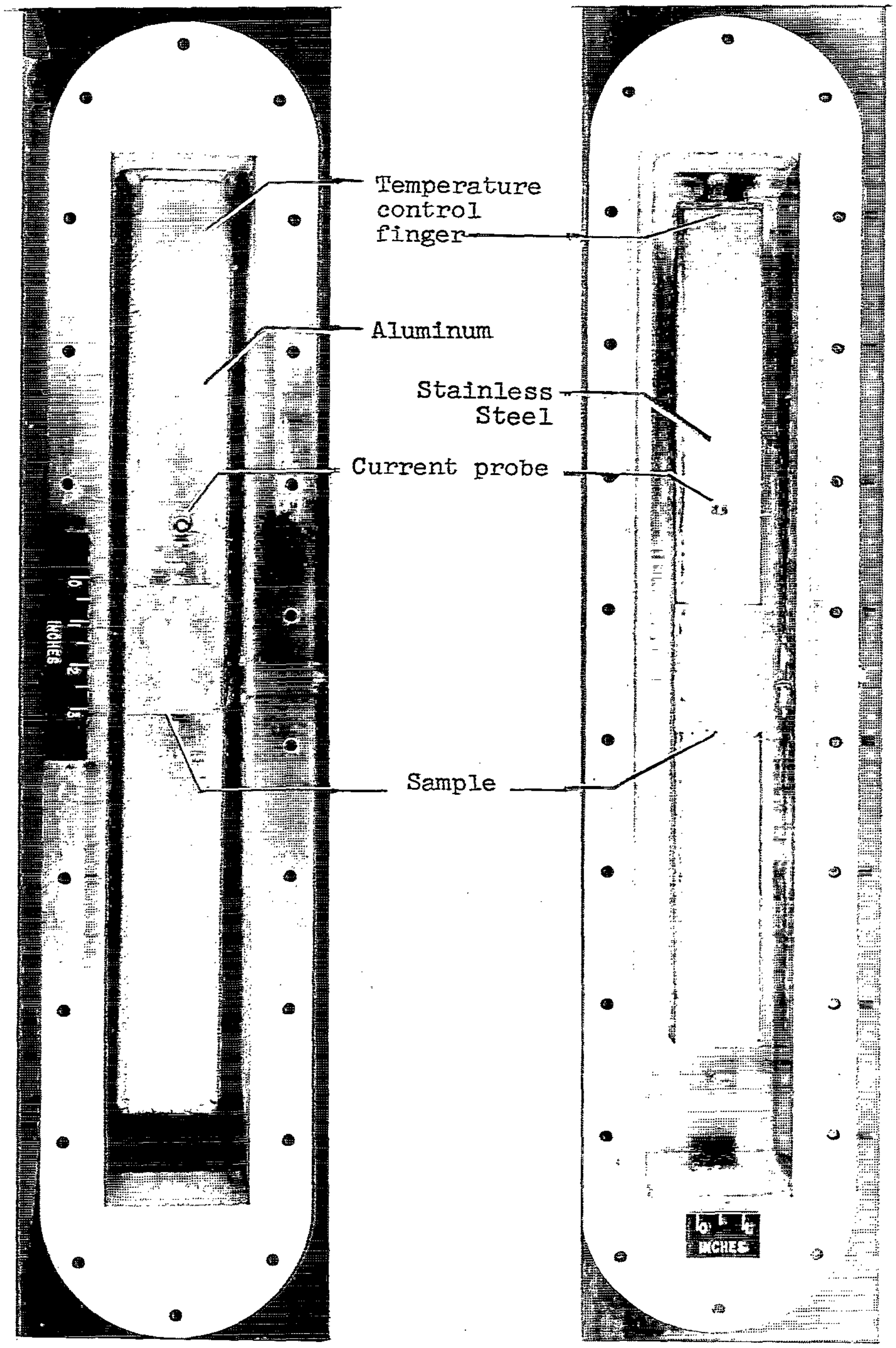


Figure 1.- Beam-handling and sample-mounting system used in radiation tests of meteoroid detectors.



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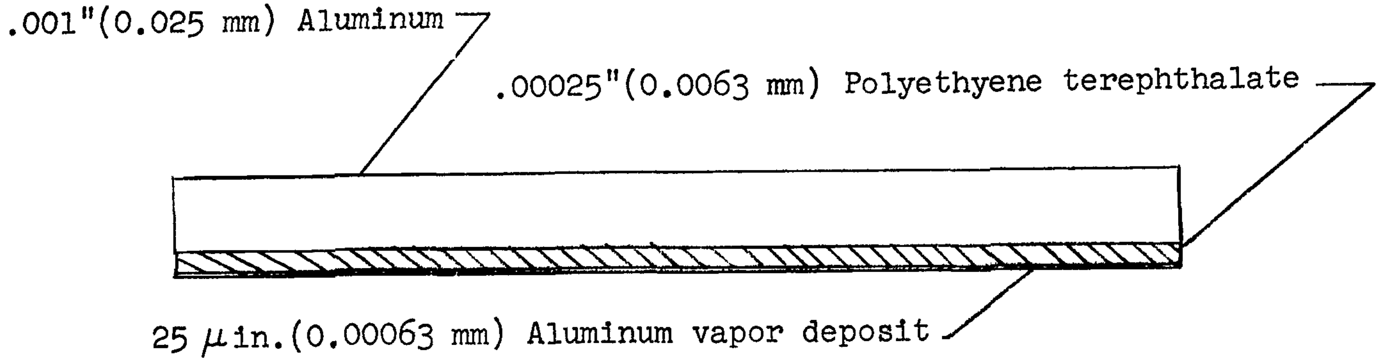
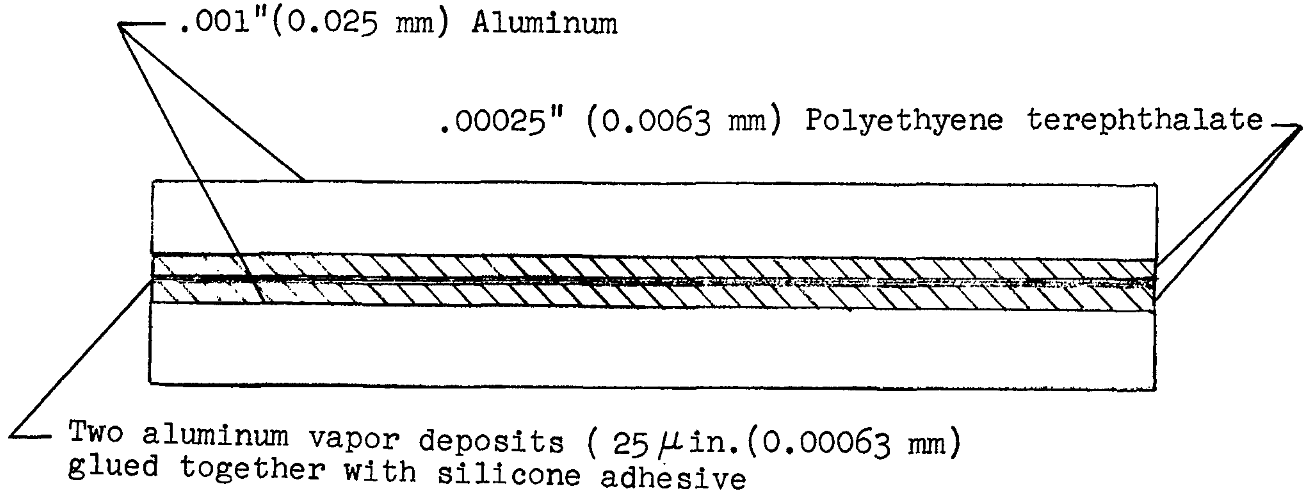
(a) Chamber used for elevated temperature.

(b) Chamber used for liquid-nitrogen temperature.

Figure 2.- Target chambers used in radiation tests of meteoroid detectors.

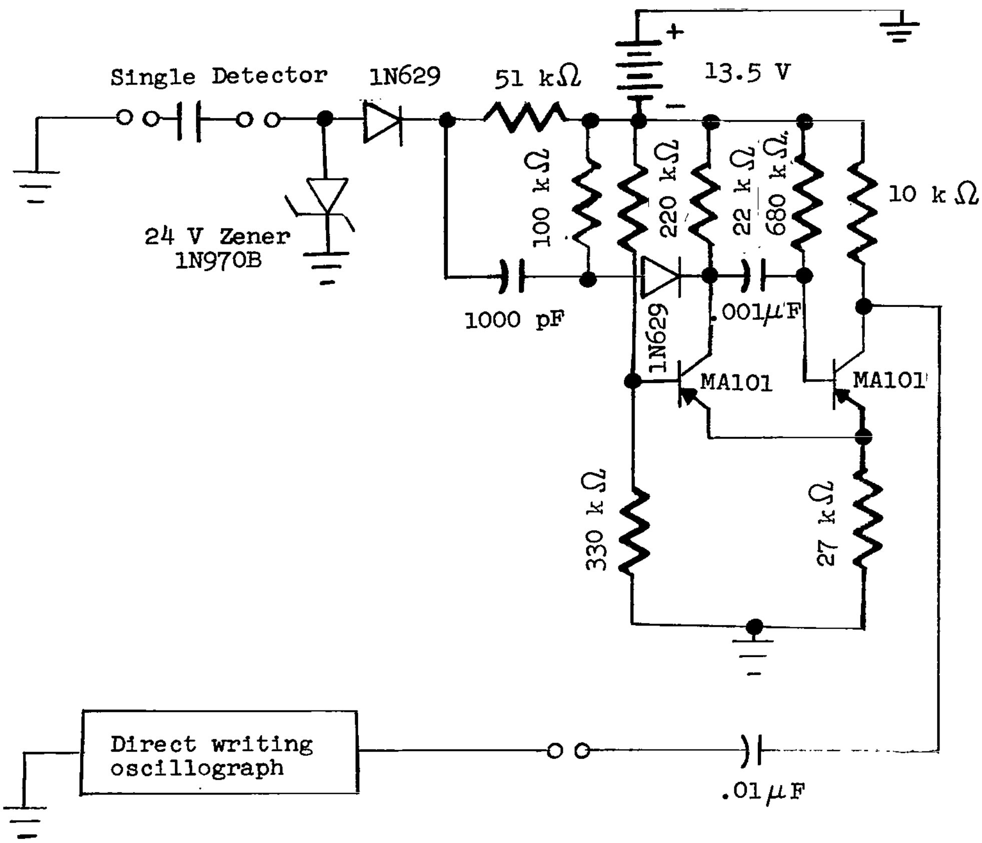


(a) Single-layer meteoroid detector.

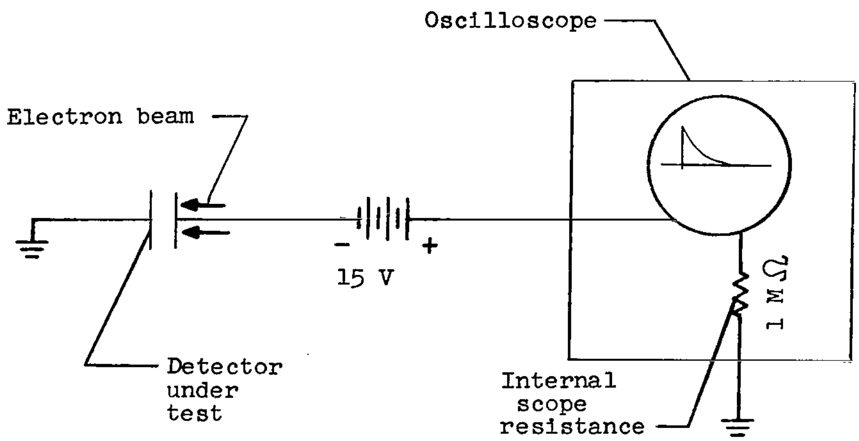


(b) Coincidence-type meteoroid detector.

Figure 3.- Cross section of meteoroid detector sample.

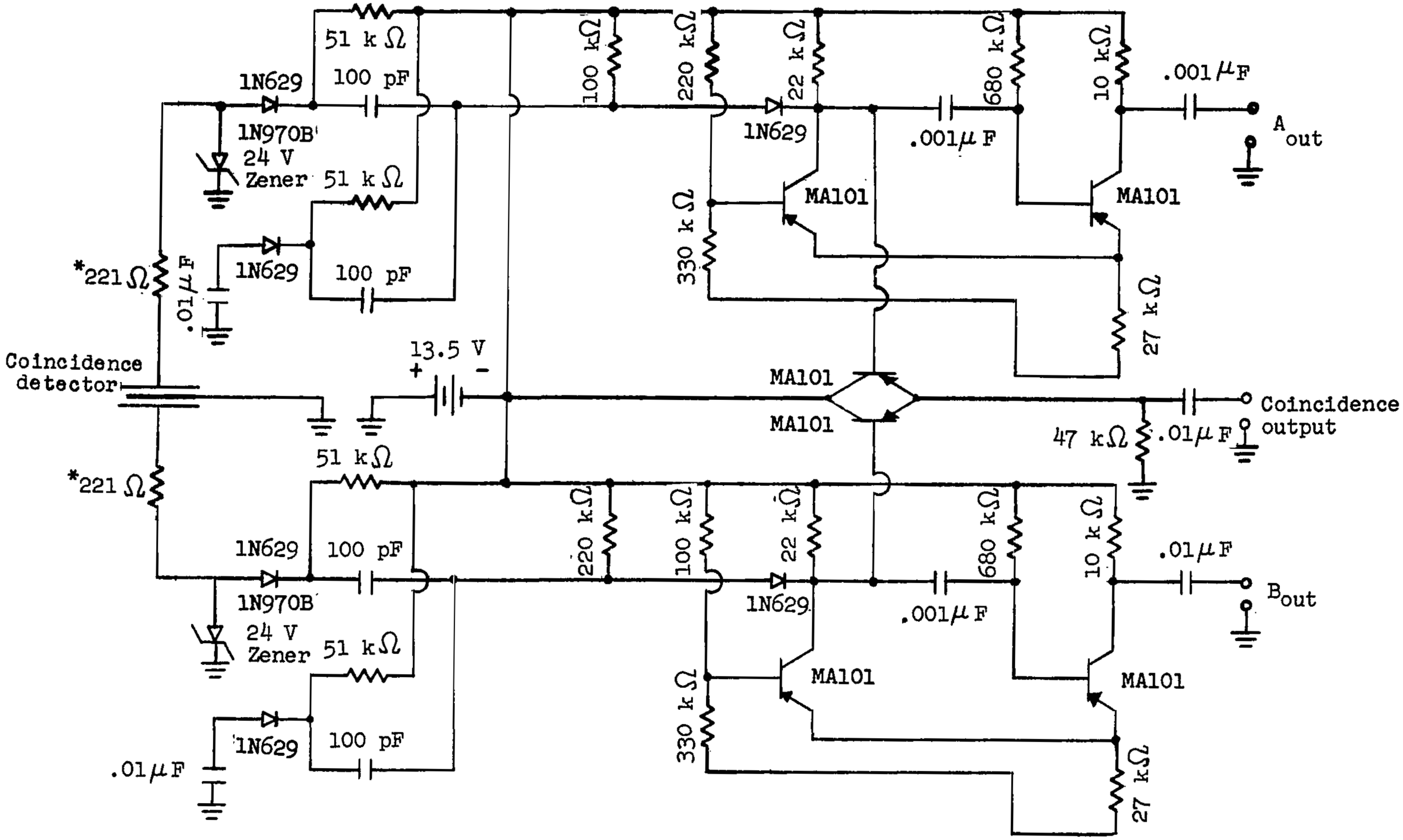


(a) Pulse detection circuit for single-layer detector.



(b) Circuit used with single detector to obtain pulse height and shape.

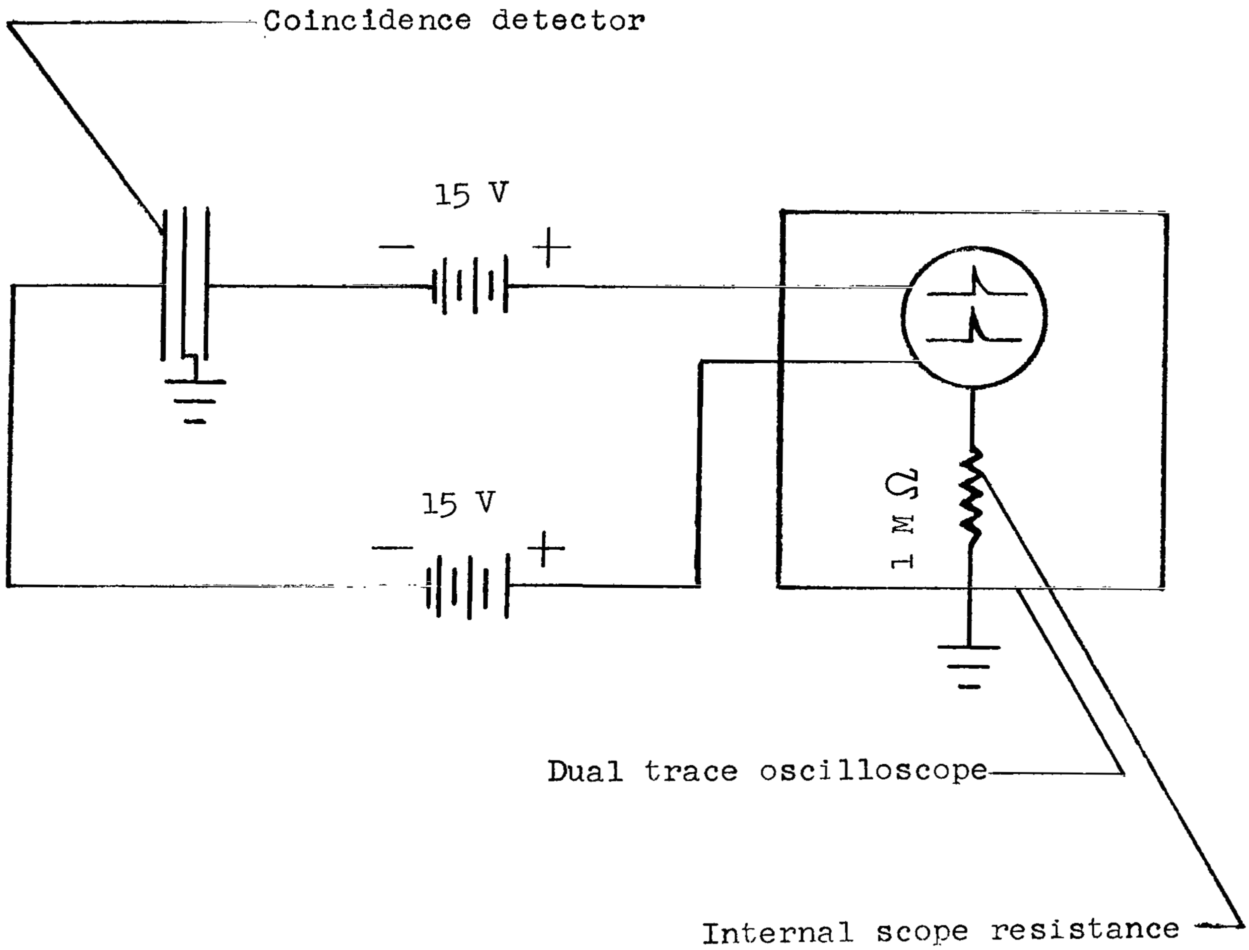
Figure 4.- Test circuits used in radiation tests of single-layer meteoroid detector.



*The 221-Ω resistors provide additional damping and were not installed in the original circuit. Discussion of this modification is included in text.

(a) Pulse detection circuit for coincidence detector.

Figure 5.- Test circuits used in radiation tests of coincidence detector.



(b) Circuit used to obtain photographs of pulse height and shape from the coincidence detector.

Figure 5.- Concluded.

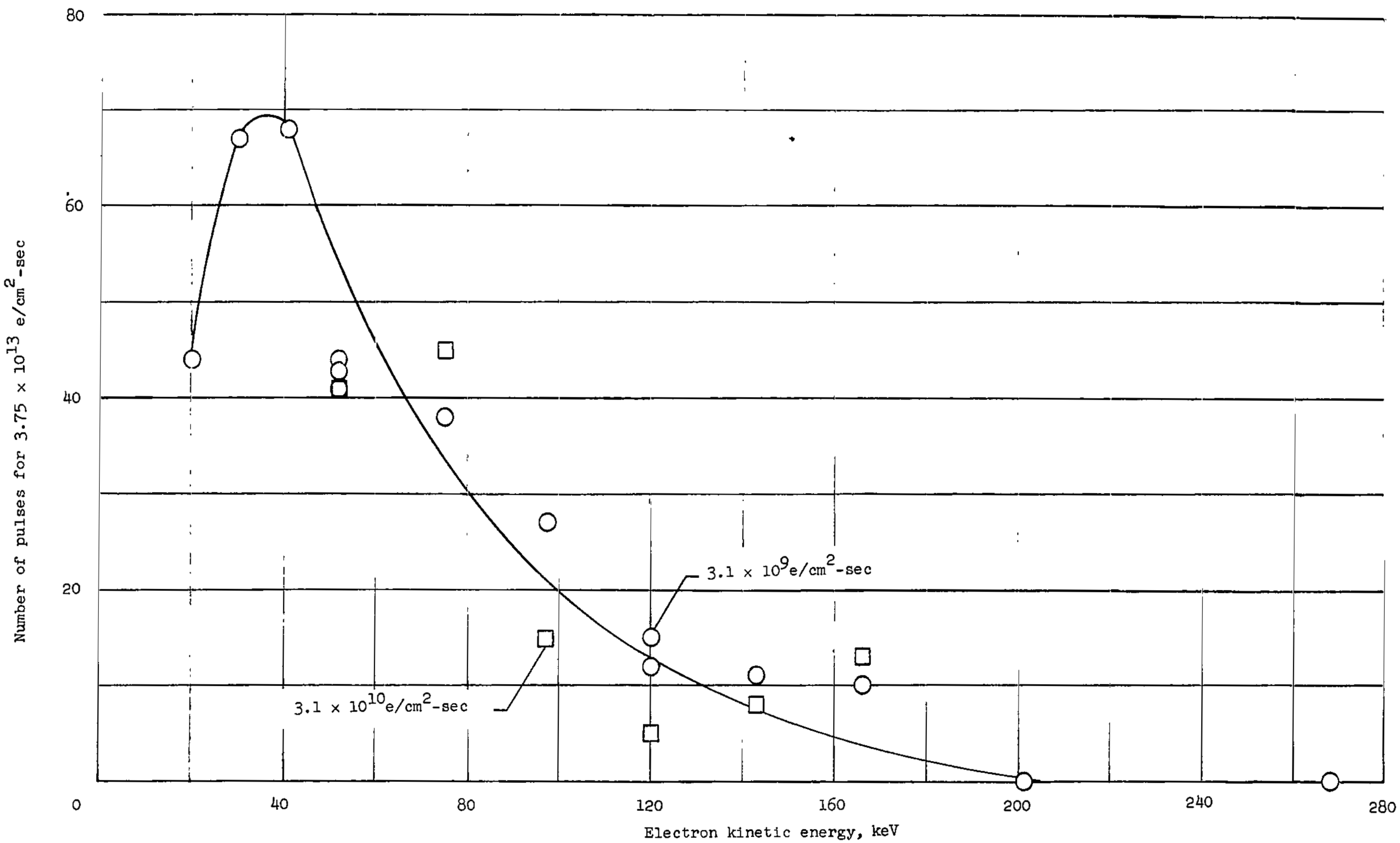
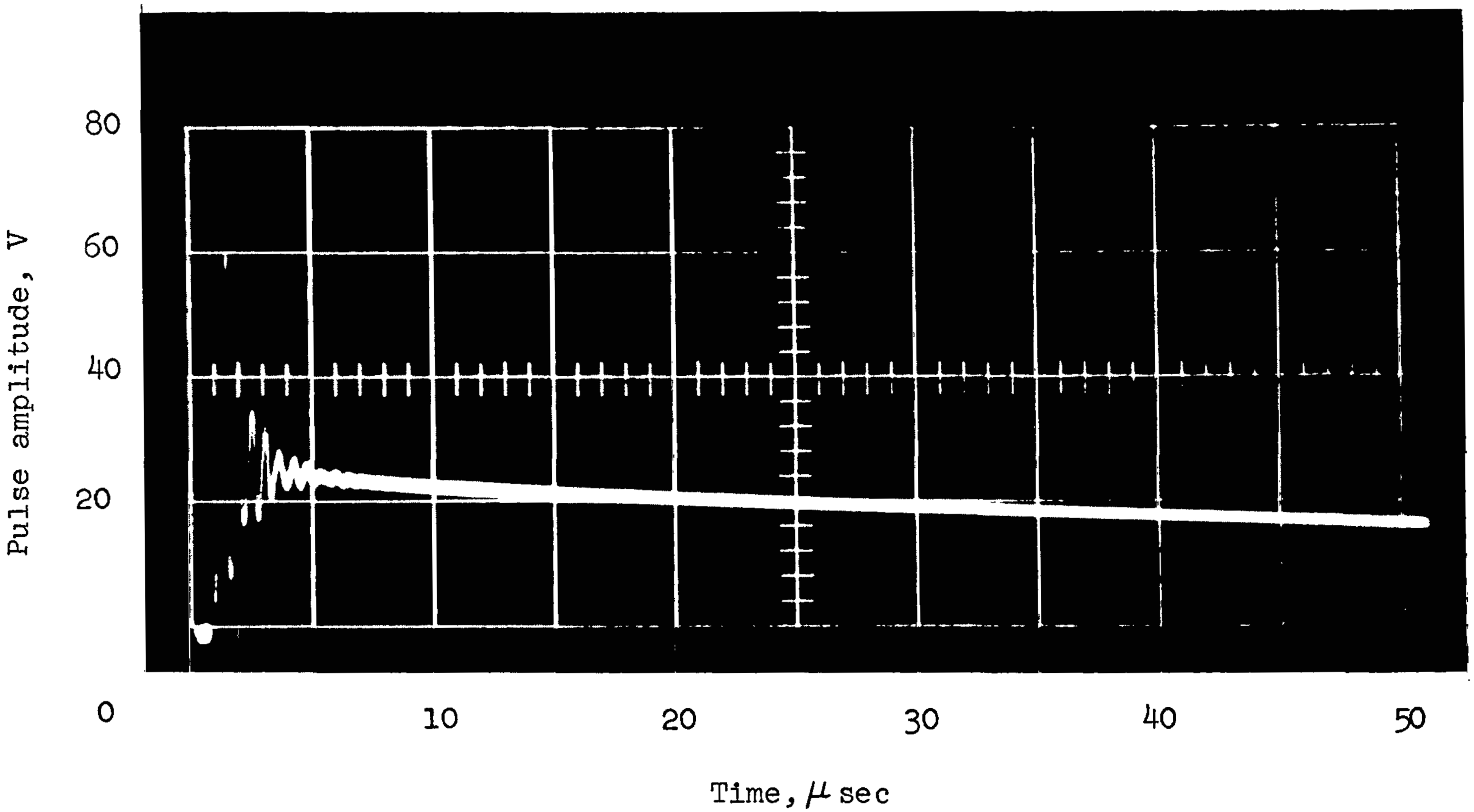
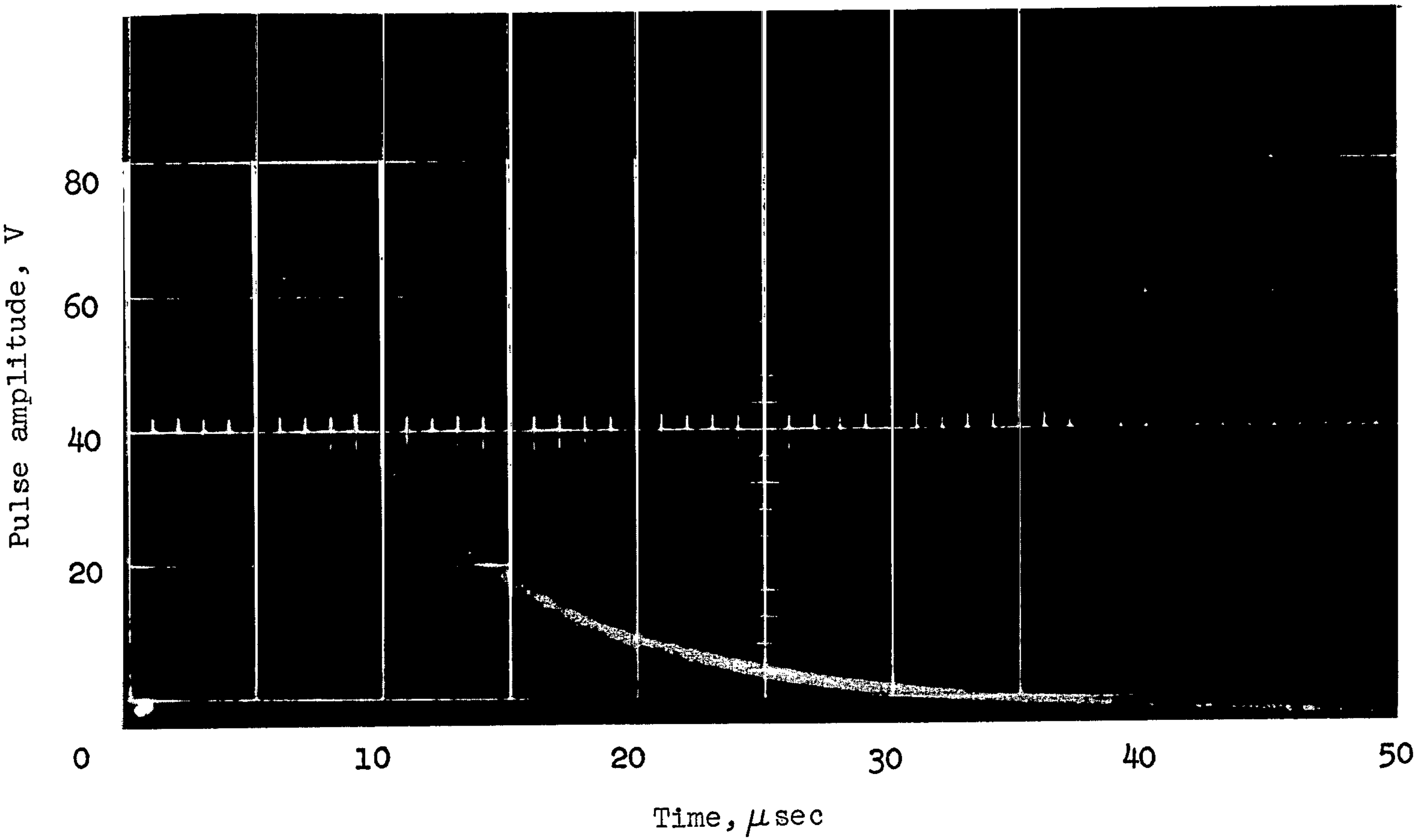


Figure 6.- Dependence of number of pulses for 3.75×10^{13} e/cm^2 on electron kinetic energy. Temperature, 77° K.



(a) Typical pulse.

Figure 7.- Shape of pulses from single-layer detector. Dose rate, 3.1×10^9 e/cm^2 at 52 keV.



(b) Pulse with amplitude greater than 80 V.

Figure 7.- Concluded.

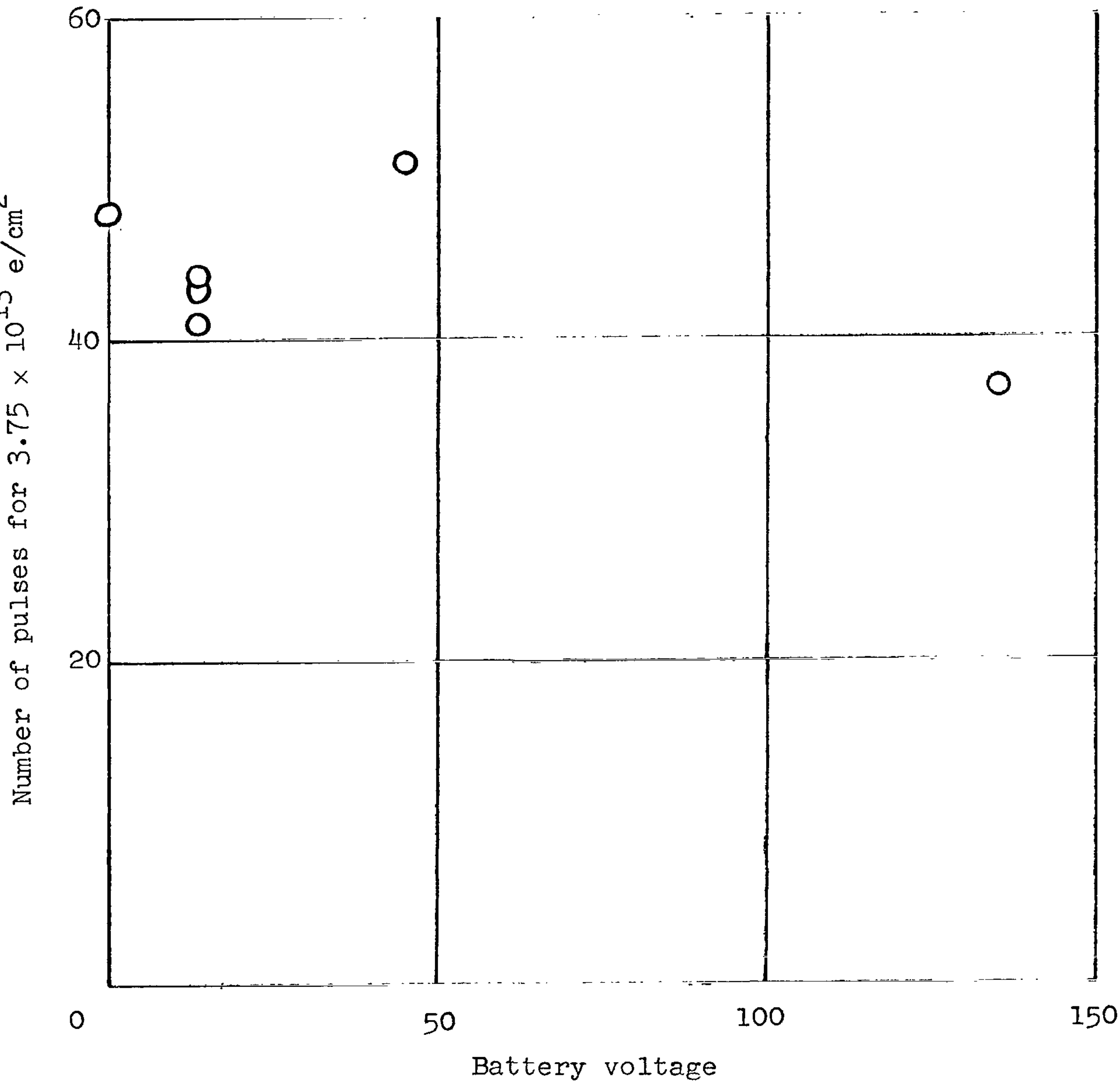


Figure 8.- Effect of battery voltage on number of pulses for 3.75×10^{13} e/cm^2. Temperature, 77° K; electron kinetic energy, 52 keV; dose rate, 3.1×10^9 e/cm^2-sec; triggering levels, 1.0, 1.0, 3.5, and 9.6 V for battery voltages of 0, 13.5, and 135 V, respectively.

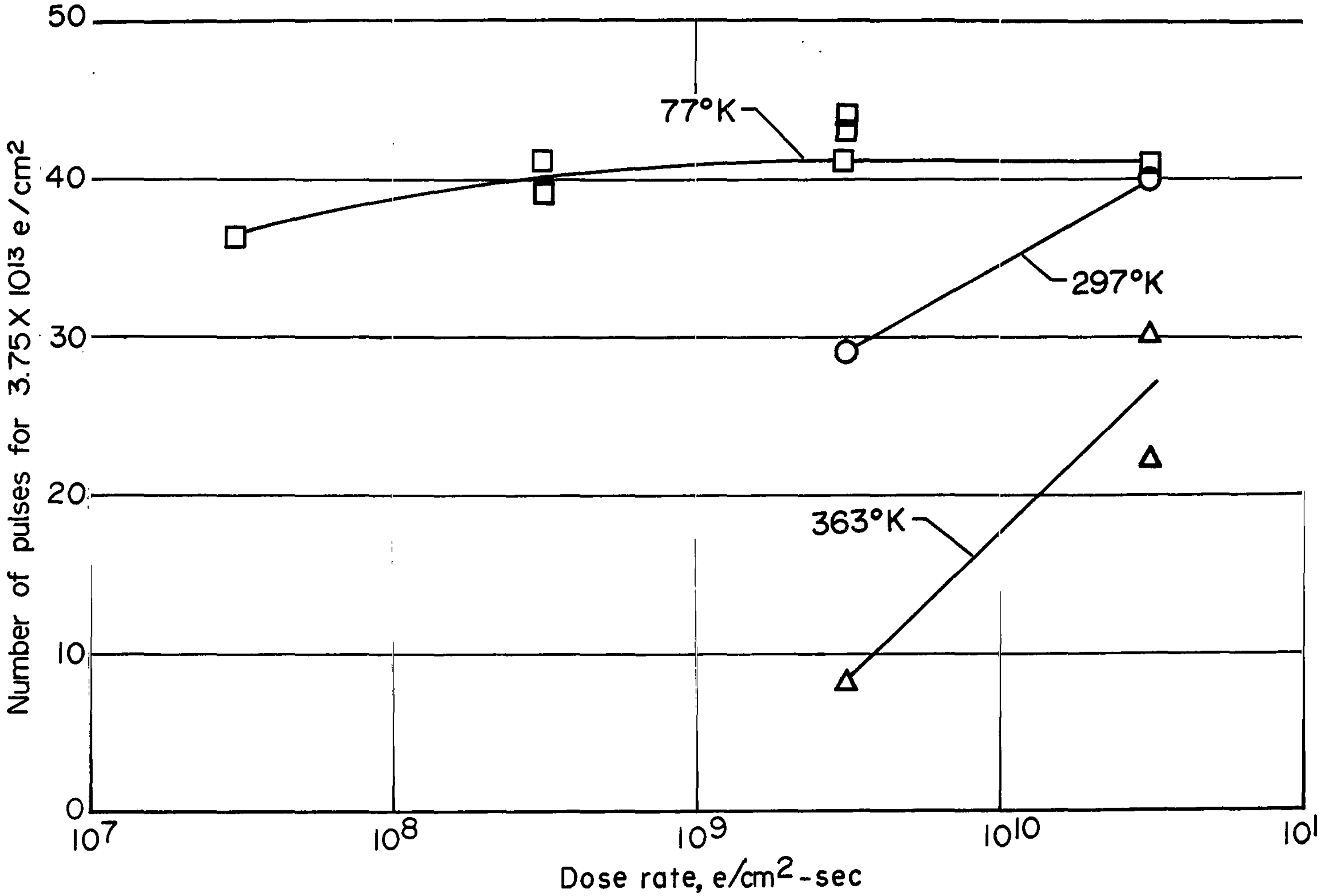


Figure 9.- Dependence of number of pulses on electron dose rate at an incident kinetic energy of 65 keV and temperatures of 77° K, 297° K, and 363° K. (This figure reproduced from ref. 14.)

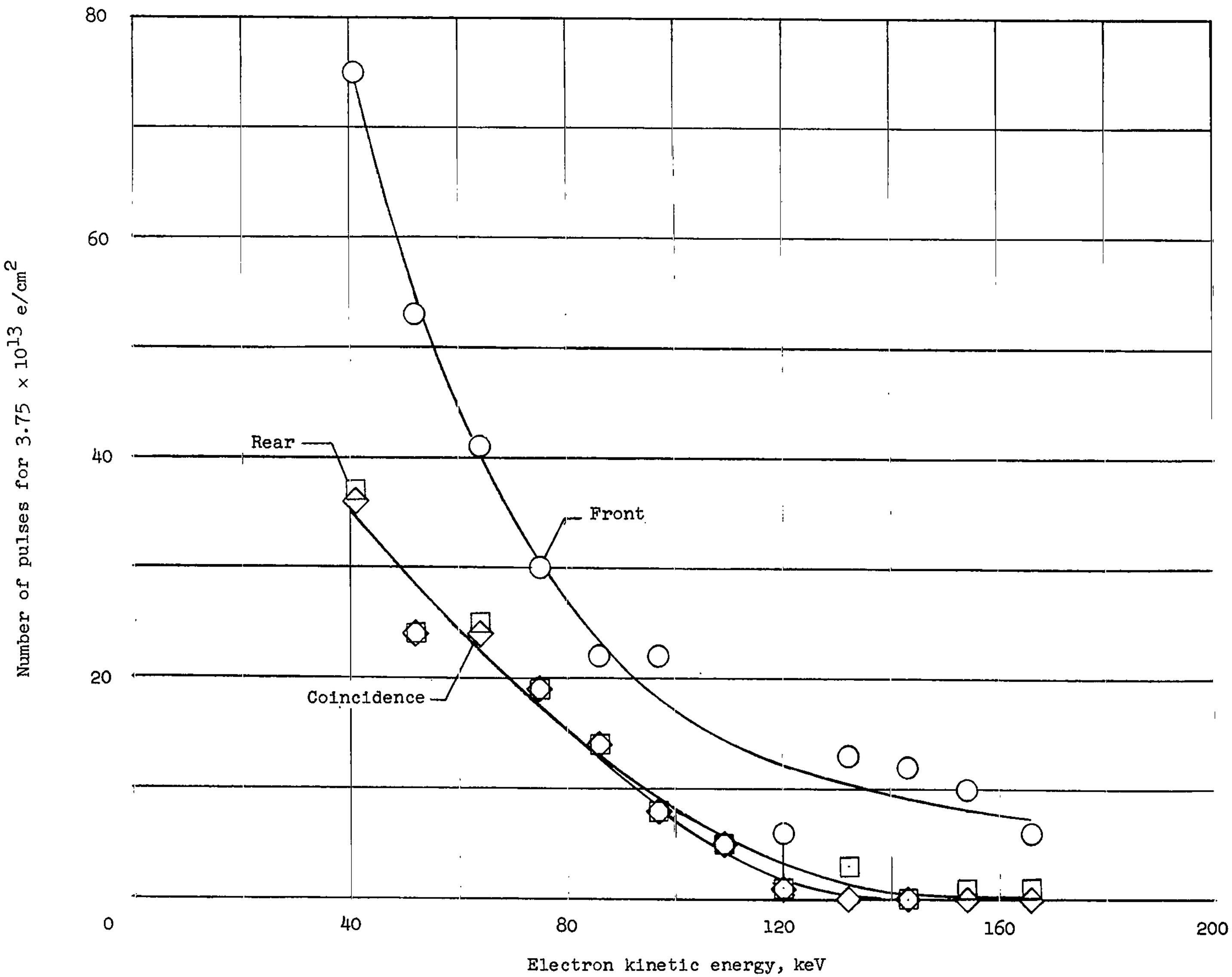
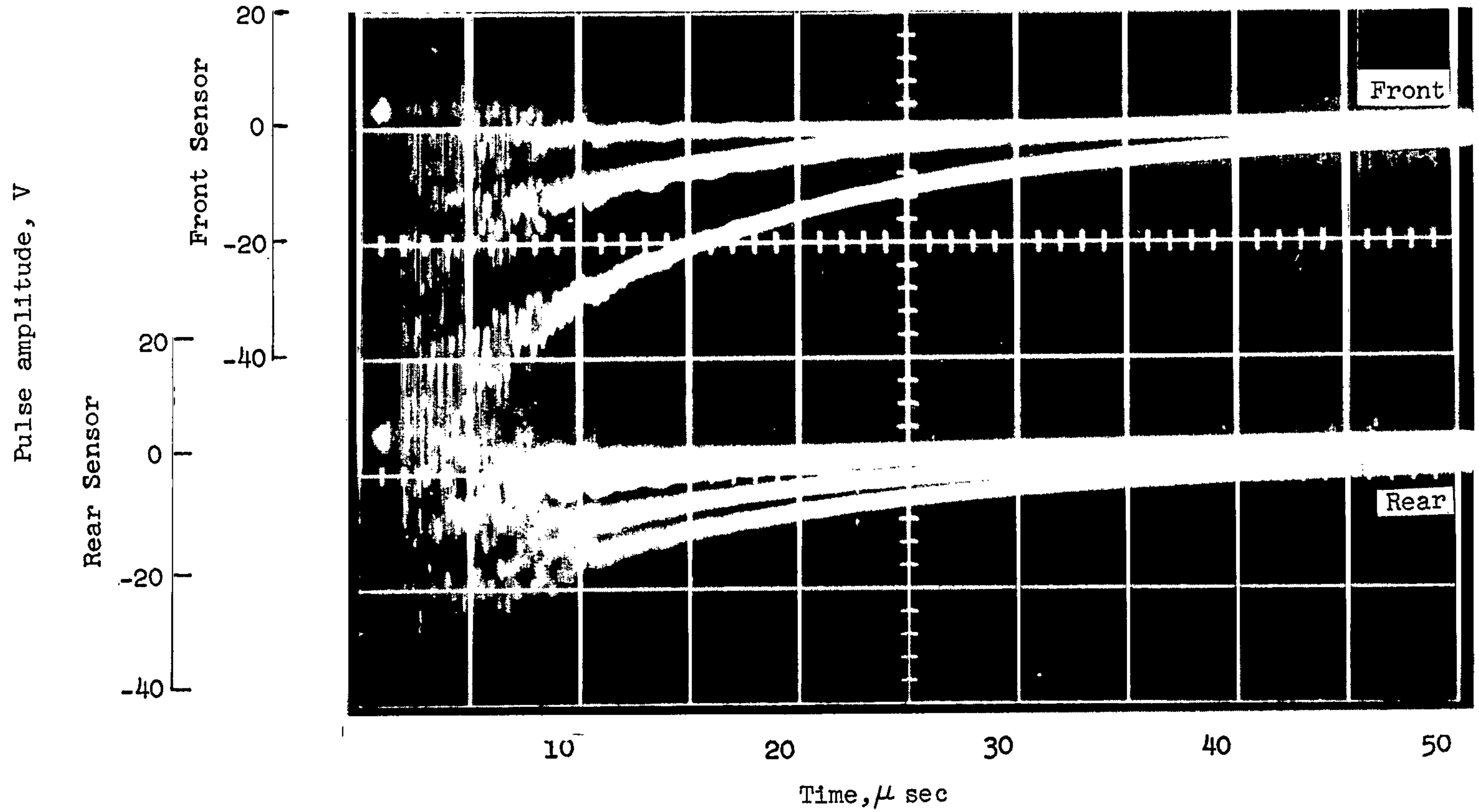
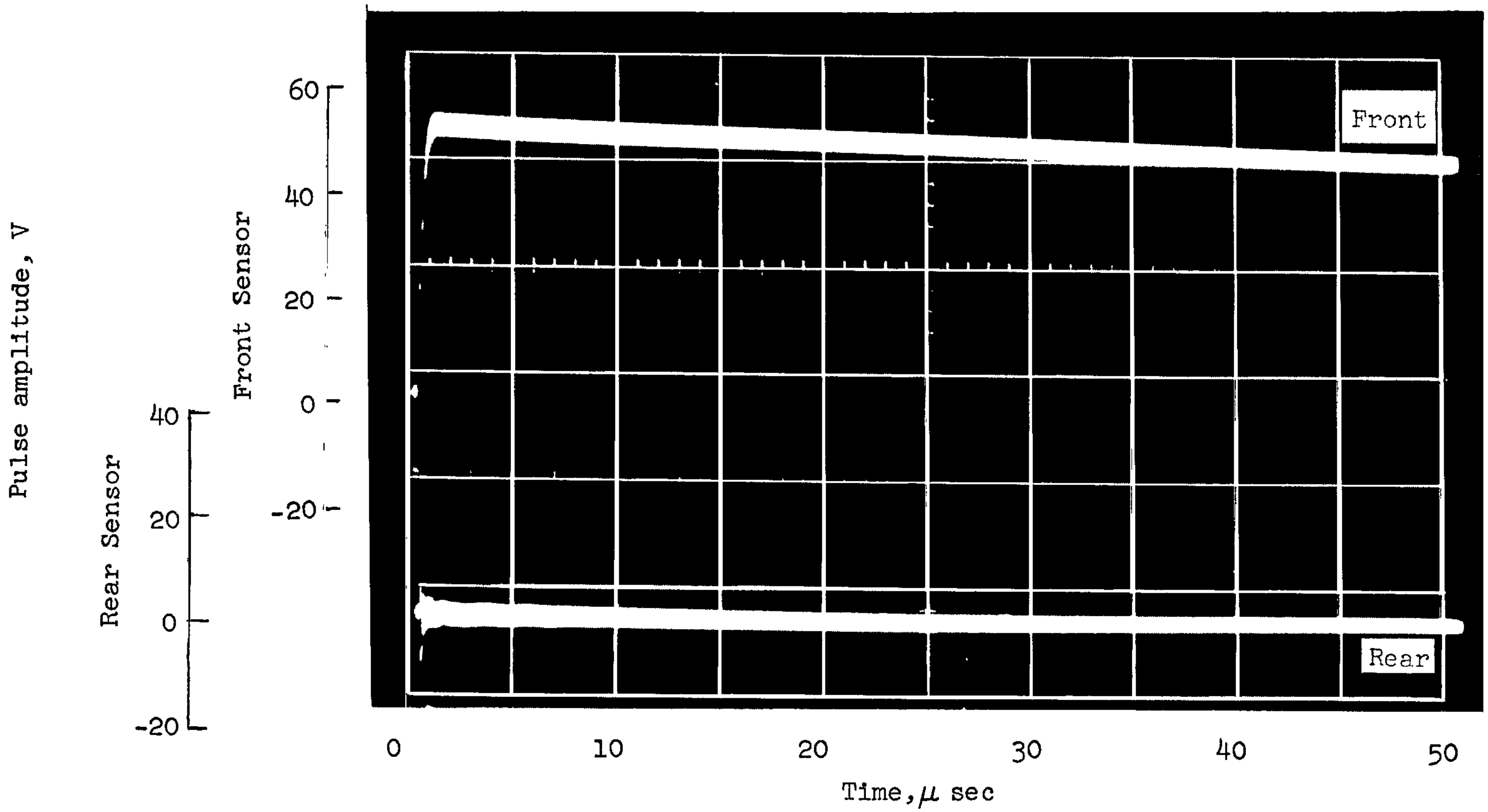


Figure 10.- Dependence of the number of pulses (for 3.75×10^{13} e/cm^2) on the electron kinetic energy for the coincidence detector. Temperature, 77° K; dose rate, 3.1×10^{10} e/cm^2-sec; no damping resistors used in circuit.



(a) No damping resistors.

Figure 11.- Shape of pulses occurring in each of the two layers of a coincidence detector. Dose rate, 3.1×10^9 e/cm^2 at 52 keV.



(b) With damping resistors (221 Ω) in each signal lead.

Figure 11.- Concluded.

NASA-Langley, 1966 L-4556

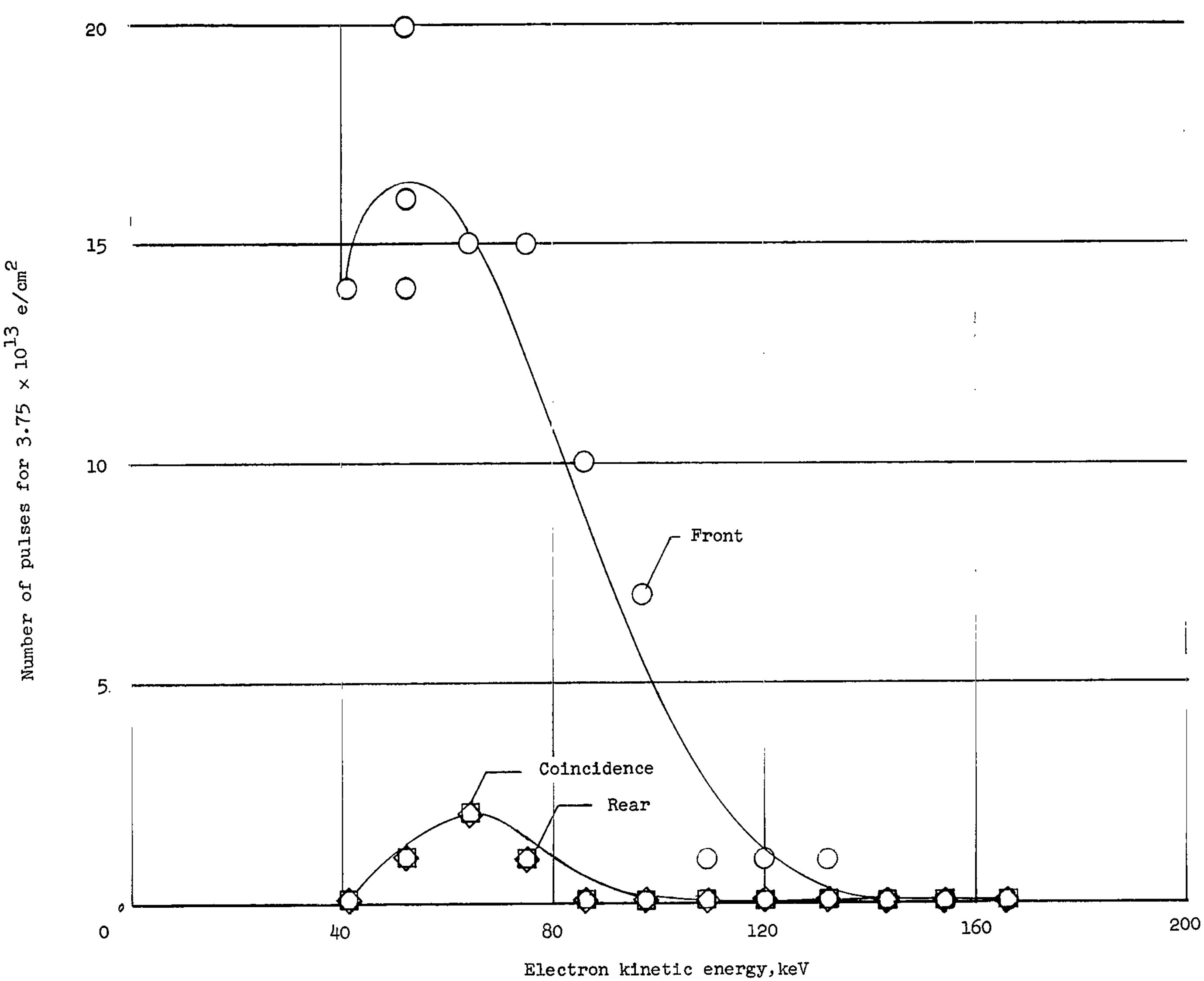


Figure 12.- Dependence of number of pulses (for 3.75×10^{13} e/cm^2) on the electron kinetic energy for the coincidence detector. Temperature, 77° K; dose rate, 3.1×10^{10} e/cm^2-sec; with damping resistors (221 Ω) in each signal lead.

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